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E-4B CREW FATIGUE ASSOCIATED WITH 30-HOUR IOT&E MISSION

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William F. Storm, Ph. D.

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Final Report for Period 1 February 1978 - 31 March 1980

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This final report was submitted by personnel of the Crew Performance Branch, Crew Technology Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks AFB, Texas, under job order 7930-10-28.

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The operational personnel who participated in this study were fully briefed on all procedures prior to participation in the study.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

William F. Storm

WILLIAM F. STORM, Ph.D.
Project Scientist

Bryce O. Hartman

BRYCE O. HARTMAN, Ph.D.
Supervisor

Roy L. DeHart

ROY L. DEHART
Colonel, USAF, MC
Commander

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Air Force Test and Evaluation Center (AFTEC) conducted an independent 45-day IOT&E of the Advanced Airborne Command Post (E-4B aircraft) system from 27 December 1978 to 11 February 1979. A 30-hour continuously airborne mission was flown 6-7 February 1979 to demonstrate the extended mission capability of the E-4B system. Using a battery of psychobiological measures, the Crew Technology Division of the USAF School of Aerospace Medicine (USAFSAM/VN) evaluated crew fatigue associated with the extended mission. The battery consisted of sleep surveys, subjective fatigue ratings, and mood surveys, as well as endocrine/

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20. ABSTRACT (Continued)

metabolic indices derived from urine samples. Data were systematically collected from 66 crewmen at 4-hour intervals during the mission and for 3 1/2 days after the mission. The data were reduced for six functional crew groups: flightcrew, stewards, radio operators, radio maintenance technicians, aircraft maintenance technicians, and the National Emergency Airborne Command Post (NEACP) battle staff. Fatigue and stress levels that occurred during the 30-hour mission were moderate and not suggestive of compromises in performance and safety. Fragmented sleep acquired in the bunks and passenger seats was of restorative value and contributed to the abeyance of severe fatigue and negative mood states during the mission. Severe levels of subjective fatigue were reported a few hours after mission completion, but after 2 nights of uninterrupted sleep in the home environment, the crews were sufficiently recovered to resume normal ground and flight duties.

PREFACE

My appreciation is extended to several dedicated people who contributed outstanding professional support to the success of this effort. Capt Wilbur E. George, USAF Regional Hospital/FSO, Offutt AFB, Nebraska, provided assistance during the airborne data-collection phase of this evaluation. SMSgt E. M. Neal, Air Force Test and Evaluation Center/SGL, Kirtland AFB, New Mexico, coordinated the integration of the USAFSAM requirements into the AFTEC test plan. Sgt Robin G. Chavez, USAFSAM/VNE, processed and reduced data. Personnel under the direction of Dr. Robert Reyes, USAFSAM/VNB, performed the biochemical analyses. Mr. Richard C. NcNee, USAFSAM/BRA, directed the statistical analyses.

The participating crewmen willingly supported the extended-mission biomedical evaluation in the midst of their many other test responsibilities. Their professionalism contributed significantly to the operational validity of the findings.

A special acknowledgment is extended to four people whose self-initiative and cooperative spirit made possible the postmission phase of the USAFSAM study. A grateful thank you is given to Capt William J. Baukus, Electronic Systems Division/YST, Hanscom AFB, Massachusetts; Capt Paul Davis, Oklahoma City-Air Logistics Center/MMAM; and Mr. John I. Keener and Ms. Deborah Collard, AFTEC/OA (BDM).

E-4B CREW FATIGUE ASSOCIATED WITH 30-HOUR IOT&E MISSION

INTRODUCTION

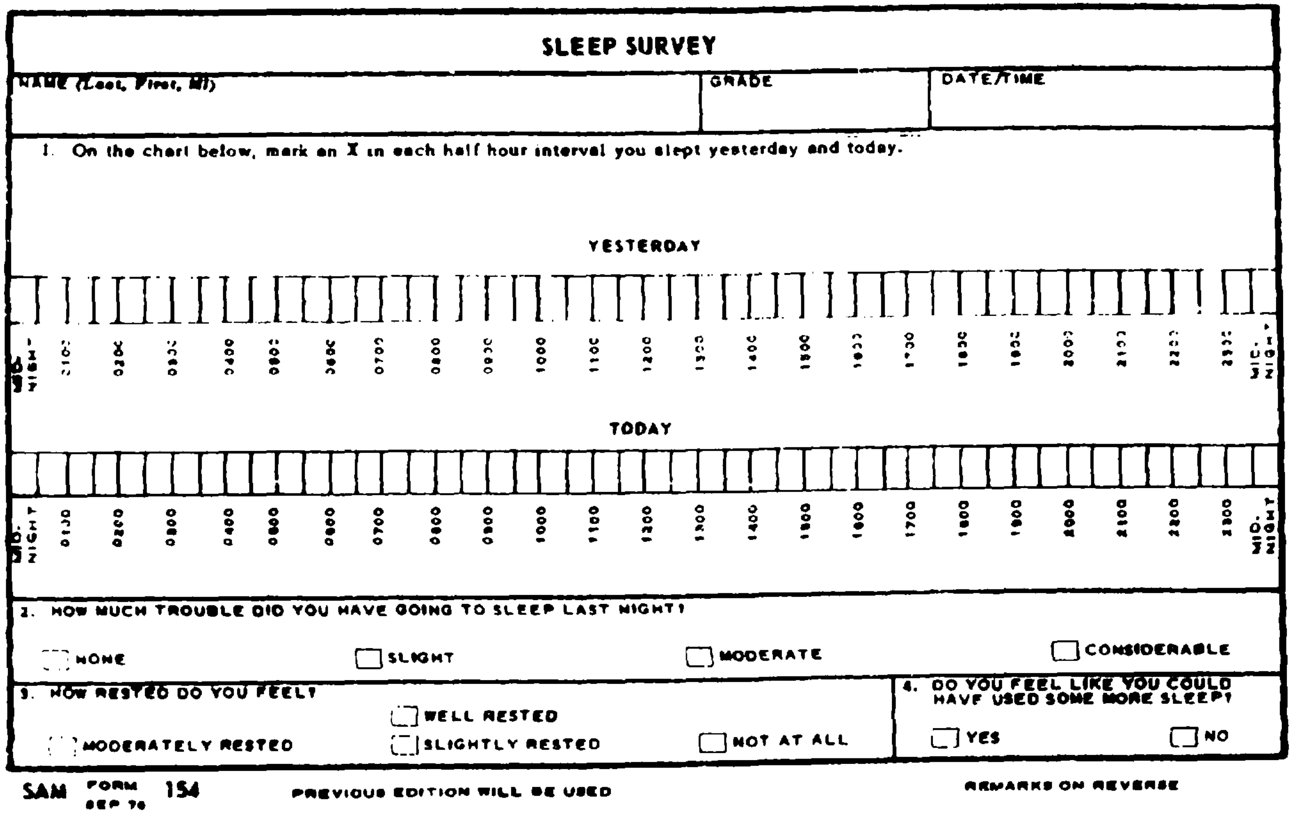
The Air Force Test and Evaluation Center (AFTEC) conducted an independent 45-day initial operational test and evaluation (IOT&E) of the Advanced Airborne Command Post (E-4B aircraft) system from 27 December 1978 to 11 February 1979. One objective of the IOT&E was to evaluate the extended-mission capability of the system, as both the Strategic Air Command (SAC) and the National Emergency Airborne Command Post (NEACP) require continuously airborne operational capability in contingency situations. In response to this requirement, a 30-hour continuously airborne mission was flown 6-7 February 1979. At the request of AFTEC/SG, the Crew Technology Division of the USAF School of Aerospace Medicine (USAFSAM/VN) evaluated crew fatigue associated with the extended mission.

METHOD

A battery of psychobiological measures was used to evaluate fatigue both during and after the 30-hour mission. This battery has been used successfully by USAFSAM/VN to evaluate crew stress and fatigue in a variety of airborne and ground operations (2,3,10,13). The measures comprising the battery have been selected and developed to minimize interference with operational duties, daily schedules, and personal activities. The battery consists of a sleep survey (SAM Form 154), a self-rating of subjective fatigue (SAM Form 136), and endocrine/metabolic indices derived from urine samples. The SAM sleep-survey form (Fig. 1) documents the hours slept during each 24-hour period and requires about 1 minute to complete. The subjective fatigue checkcard (Fig. 2) can be completed in less than a minute and results in a score ranging from 0-20 (arbitrary units), with lower scores indicating greater fatigue (17).

The urinary measures consist of norepinephrine (NE), an index of sympathetic nervous system activity; epinephrine (E), adrenomedullary activity; 17-hydroxycorticosteroid (17-OHCS), adrenocortical activity; urea, protein catabolism; amino nitrogen, adrenocortical steroid activity; and sodium (Na) and potassium (K), mineral metabolism. Each urinary measure is adjusted to a quantity per 100 mg creatinine. The ratio of sodium to potassium (Na/K) is calculated as an index of metabolic activity (homeostasis). The use of a creatinine-based ratio corrects for variations in the timing of urine collections, and for variations in subject age and body size. Changes in the urinary levels of these selected biochemical measures can occur as a result of psychological and biological demands made on the individuals (10).

For this study, the copyrighted Profile of Mood States (POMS) was also included in the measurement battery (16). This instrument assesses an individual's current affective state on six independent dimensions: anxiety, depression, anger, vigor, fatigue, and confusion. The POMS survey requires



SLEEP SURVEY

NAME (Last, First, MI) | GRADE | DATE/TIME

1. On the chart below, mark an X in each half hour interval you slept yesterday and today.

YESTERDAY

MID-NIGHT 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 MID-NIGHT

TODAY

MID-NIGHT 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 MID-NIGHT

2. HOW MUCH TROUBLE DID YOU HAVE GOING TO SLEEP LAST NIGHT?

NONE | SLIGHT | MODERATE | CONSIDERABLE

3. HOW RESTED DO YOU FEEL?

MODERATELY RESTED | WELL RESTED | SLIGHTLY RESTED | NOT AT ALL

4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP?

YES | NO

SAM FORM SEP 76 154 PREVIOUS EDITION WILL BE USED REMARKS ON REVERSE

Figure 1. SAM Form 154. A sleep survey was completed at 0800 (or upon awakening) each day of the study.

NAME AND GRADE	TIME/DATE

INSTRUCTIONS: Make one and only one (✓) for each of the ten items. Think carefully about how you feel RIGHT NOW.

STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7. PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

PREVIOUS EDITION WILL BE USED

SAM FORM SEP 76 136 SUBJECTIVE FATIGUE CHECKCARD

Figure 2. SAM Form 136. A subjective fatigue survey was completed at 4-hour intervals around-the-clock during the mission and at 4-hour intervals during typical waking hours after the mission.

5-10 minutes for completion. The crewmen were instructed to respond to the POMS according to "how you feel right now." The scores for each affective dimension are standardized T-scores with a mean of 50 and a standard deviation of 10, based on normative data from 856 college students. For each of the six POMS scales, the larger the T-score the more prevalent the affective state.

Prior to the extended mission, all test participants were briefed on the purpose, procedures, and data-collection schedule for each measure so that each participant could assume major responsibility for the proper and timely collection of his own data. The 66:1 ratio of participants to study director and the need for at-home data collection during off-duty days after the mission made a self-administrative methodology practical and efficient. The E-4B test participants were very cooperative.

The 30-hour mission departed Andrews AFB, Maryland at 0730 CST (0830 EST), 6 February, and landed at Offutt AFB, Nebraska at 1330 CST, 7 February. Offutt AFB was the home base for all but two of the study participants. Data were collected systematically during the mission and for 3 1/2 days after the

TABLE 1. USAFSAM DATA-COLLECTION SCHEDULE

Date	Time	Measure			
		Fatigue	Sleep	Mood	Urine
6 Feb (Tues)	0800*	X	X	X	
	1200*	X			
	1600*	X			
	2000*	X			
	2400*	X			
7 Feb (Wed)	0400*	X			
	0800*	X	X	X	
	1200*	X			
	1600	X		X	X
	2000	X			
8 Feb (Thur)	0800	X	X		
	1200	X			
	1600	X			X
	2000	X			
9 Feb (Fri)	0800	X	X		
	1200	X			
	1600	X		X	X
	2000	X			
10 Feb (Sat)	0800	X	X		
	1200	X			
	1600	X			X
	2000	X			

*airborne

mission, in accordance with the schedule presented in Table 1. The times of day are presented in the text, tables, and figures of this report as Central Standard Time. The data-collection schedule served as a guideline. Participants were never awakened for data collection. Some data were collected as much as 60-90 minutes on either side of the scheduled times to allow for uninterrupted work and sleep periods. A sleep survey was completed at 0800 (or upon awakening) each day. Subjective fatigue was collected (SAM Form 136) at 4-hour intervals around-the-clock during the mission, and after the mission at 4-hour intervals during typical waking hours. The POMS survey was completed

twice during the mission (at 0800 in both cases) and twice after the mission (at 1600 in both cases). Starting on the afternoon of mission completion, urine samples were collected at 1600 daily. Due to mission schedule requirements, the NEACP staff participated in only the airborne portion of the study.

During the airborne mission, study materials were available at strategic points in the aircraft. The SAM study director was onboard to observe, answer questions, and collect completed materials. Immediately after landing at Offutt AFB, each participant was given a supply of study materials and urine collection bottles to take home for self-administration during the 3 1/2-day postmission period. The urine bottles contained a small amount of dilute acid to serve as a preservative. The crewmen were instructed to freeze each sample as soon as possible after collection. The study director was available daily at the E-4B test office to collect materials from the participants at their convenience.

The SAM subjective fatigue and sleep data from the 66 test participants were grouped into six functional crew categories: 9 flight crewmen (5 pilots, 2 navigators, 2 flight engineers), 4 stewards, 17 radio and teletype operators (COMM), 12 radio maintenance personnel (AMS), 10 aircraft maintenance personnel (OMS/FMS), and 14 members of the NEACP battle staff. Although the 4 stewards formed a very small sample, their unique duties and schedule necessitated treating them as an independent group. Such a small sample, however, severely limits statistical description and analyses, so these data were not subjected to all evaluations.

Data were incomplete for various reasons. As expected, some of the 66 crewmen slept through one or two data-collection intervals. During the mission, no data were collected from the OMS/FMS and NEACP groups at 0400 because they were all sleeping. After the mission, some participants departed Offutt AFB on other missions before data collection was completed. A few participants never submitted any postmission data. Mean values presented in text, tables, and figures are composites of estimates from the various analyses.

RESULTS

Hours Slept

The amount of sleep acquired was documented for the day before the mission, the 30-hour mission, and each of the 3 days following the mission. An initial analysis of all 5 days indicated that mission sleep data had significantly greater variability than the data for the other 4 days. Therefore, four separate analyses were performed, in which each nonflying day was individually compared with the mission-day (Table 2). Because of missing data, best-estimates of means were calculated for the various comparisons, resulting in two sets of means for the mission day: one set for comparison to premission sleep (upper portion of Table 2), and one set for comparison with mean hours slept during each postmission day (lower portion of Table 2). As noted earlier, postmission data were not available from the NEACP crewmen. Significant group x day interactions occurred in each of the four paired analyses involving the mission day.

Table 2 shows that premission sleep was moderately to severely reduced from normal (7-8 hours per night) for all groups but stewards. Standby-alert duty schedules required some COMM, OMS/FMS, and NEACP personnel to remain awake during the 20 hours preceding takeoff at 0730 on 6 February.

TABLE 2. MEAN HOURS SLEPT DURING PREMISSION, MISSION, AND THREE POSTMISSION DAYS

Premission vs Mission Day

	Flightcrew	Stewards	COMM	AMS	OMS/FMS	NEACP
Premission	6.1	7.0	4.9	5.8	5.5	4.3
Mission	6.3	5.4	7.5	7.8	10.1	4.7

Mission vs Each Postmission Day

	Flightcrew	Stewards	COMM	AMS	OMS/FMS
Mission	6.1	5.3	8.0	7.9	10.5
Postmission-1	10.5	10.5	11.2	9.0	9.1
Postmission-2	8.6	8.5	8.6	7.4	7.8
Postmission-3	8.2	10.3	8.1	7.0	7.6

During the mission, the overall average for sleep was 7 hours. The NEACP staff received the least sleep (4.7 hours), and the OMS/FMS group the most (10.1 hours). However, the overall range for individual sleep data during the mission was very large: 0.9-20.0 hours. The responsibilities and duties of the various groups determined when they could catch some sleep. For instance, most of the OMS/FMS personnel were much busier during the hours preceding takeoff than when airborne, while the opposite was the case for the stewards. The sleep acquired during the mission by most (72%) of the participants was fragmented into two or three intervals separated by an hour or more.

A fifth analysis simultaneously compared the sleep data for the 4 nonflying days. Only the day effect was significant ($p<.001$). The least sleep was acquired premission (5.3 hours), and the most was acquired the first postmission night (10.1 hours). Typical amounts of sleep occurred on the second and third postmission nights (8.1 and 7.8 hours respectively).

Subjective Fatigue

Interpretation of subjective fatigue scores (SAM Form 136) is based on both relative values and absolute scores. *In general*, mean subjective fatigue scores of 12 and above suggest feelings of alertness; 11 down to 8, moderate fatigue; and 7 and lower, severe fatigue. Circadian (time of day) patterns are known to occur for subjective fatigue. For the typical day worker, feelings of

alertness and freshness prevail during morning and afternoon (represented by higher and/or increasing scores), while feelings of fatigue (represented by lower and/or decreasing scores) become more prevalent in the late afternoon and evening. Fatigue can be considerable when an individual is required to be awake during normal sleeping hours (2200-0600). Because of this established circadian variation, analysis and interpretation of subjective fatigue scores should consider the time of day the data were gathered. Overall mean subjective fatigue scores reported for the SAM survey during both the mission and the postmission phases are presented in Figure 3 for all test participants. Figures 4 and 5 present the SAM subjective fatigue data further reduced for the separate crew groups. The mean values presented in these figures are not specific for any of the statistical analyses presented below, but do reflect the general trends seen in the various analyses. Figure 4 focuses attention on the within-mission patterns, while Figure 5 attends to changes across mission and postmission days for the selected times of 0800 and 2000.

Severe levels of subjective fatigue were not reported during the 30-hour mission, but moderate levels did occur as the mission progressed into the evening and early morning hours (Figs. 3 and 4). Through 1200 on 7 February, a typical circadian pattern occurred for both the overall crew means (Fig. 3) and, allowing for minor variations, the means for each crew group (Fig. 4). Even after a night of reduced and disrupted sleep, feelings of fatigue subsided during the last 6 hours of the mission which, in this case, corresponded with the time of day (0800-1600) when most people feel alert and fresh. In both Figures 3 and 4, this time-related improving subjective state is depicted by the general pattern of increasing scores (less subjective fatigue) from 2400 to 1200 on 7 February.

The subjective fatigue scores reported by all six crew groups at 0800 and 1200 during the mission, the only data-collection times common to both 6 and 7 February, were statistically analyzed for day, time, and crew-group effects. A significant ($p=.031$) increase (less fatigue) in overall mean fatigue score occurred from 0800 (score=11.3) to 1200 (score=12.0). A significant group x day interaction ($p=.046$) appears to have been caused by a relatively large decrease in mean score (greater fatigue) for the stewards on the latter part of the mission (7 Feb, Table 3).

TABLE 3. MEAN SUBJECTIVE FATIGUE SCORES FOR 0800 AND 1200 DURING 30-HR AIRBORNE MISSION

Crew group	6 Feb	7 Feb
Flightcrew	12.6	13.1
Stewards	13.9	8.6
COMM	13.2	11.4
AMS	10.7	10.9
OMS/FMS	10.2	11.7
NEACP	12.7	10.8

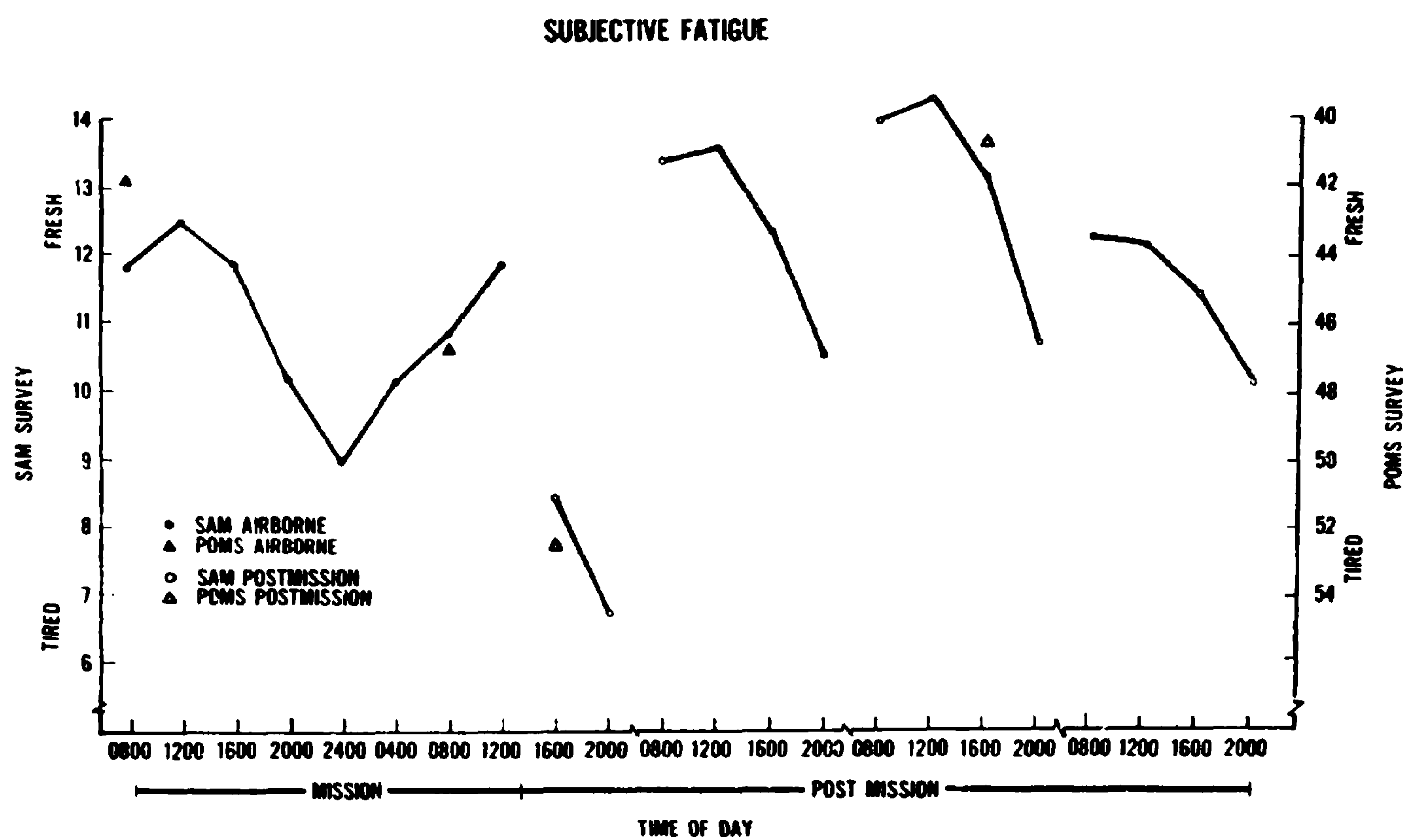


Figure 3. Mean subjective fatigue scores reported (SAM Form 136 and POMS survey) during the 30-hour mission and the 3 1/2-day postmission interval.

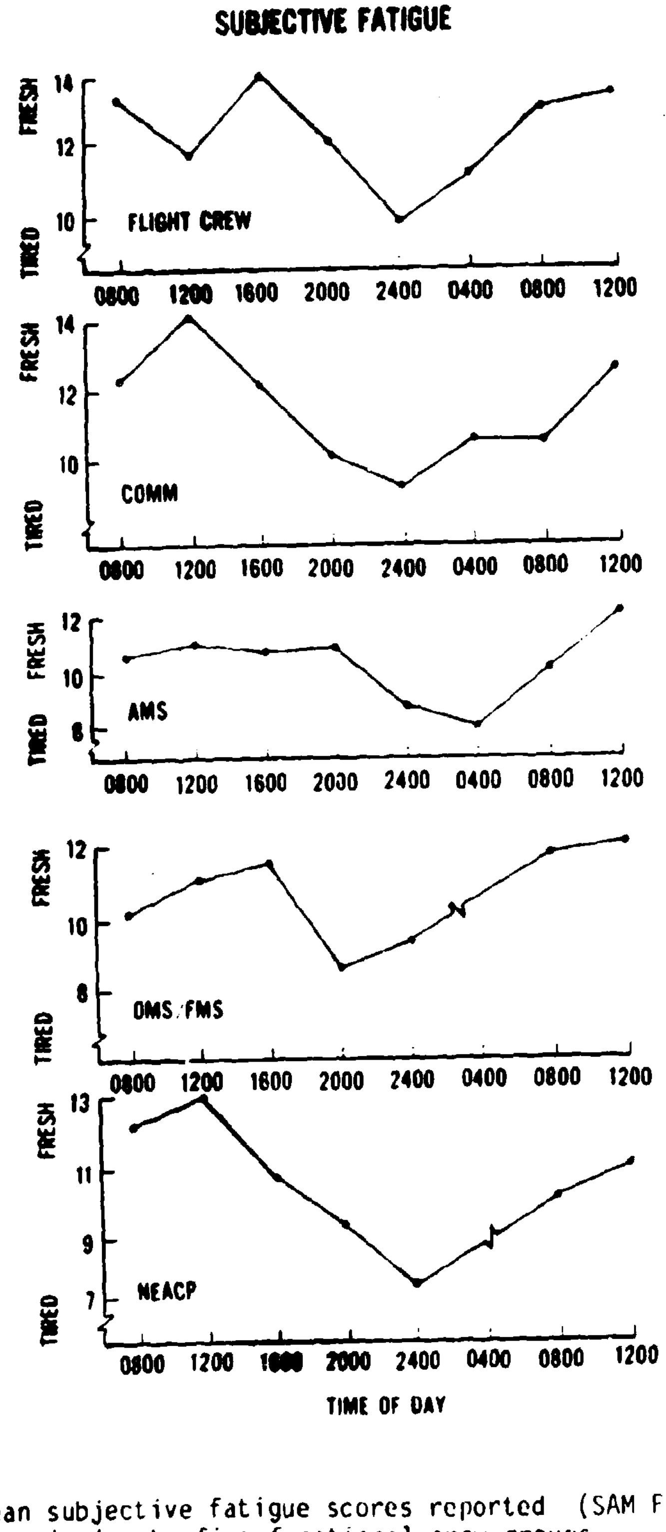


Figure 4. Mean subjective fatigue scores reported (SAM Form 136) during the mission by five functional crew groups.

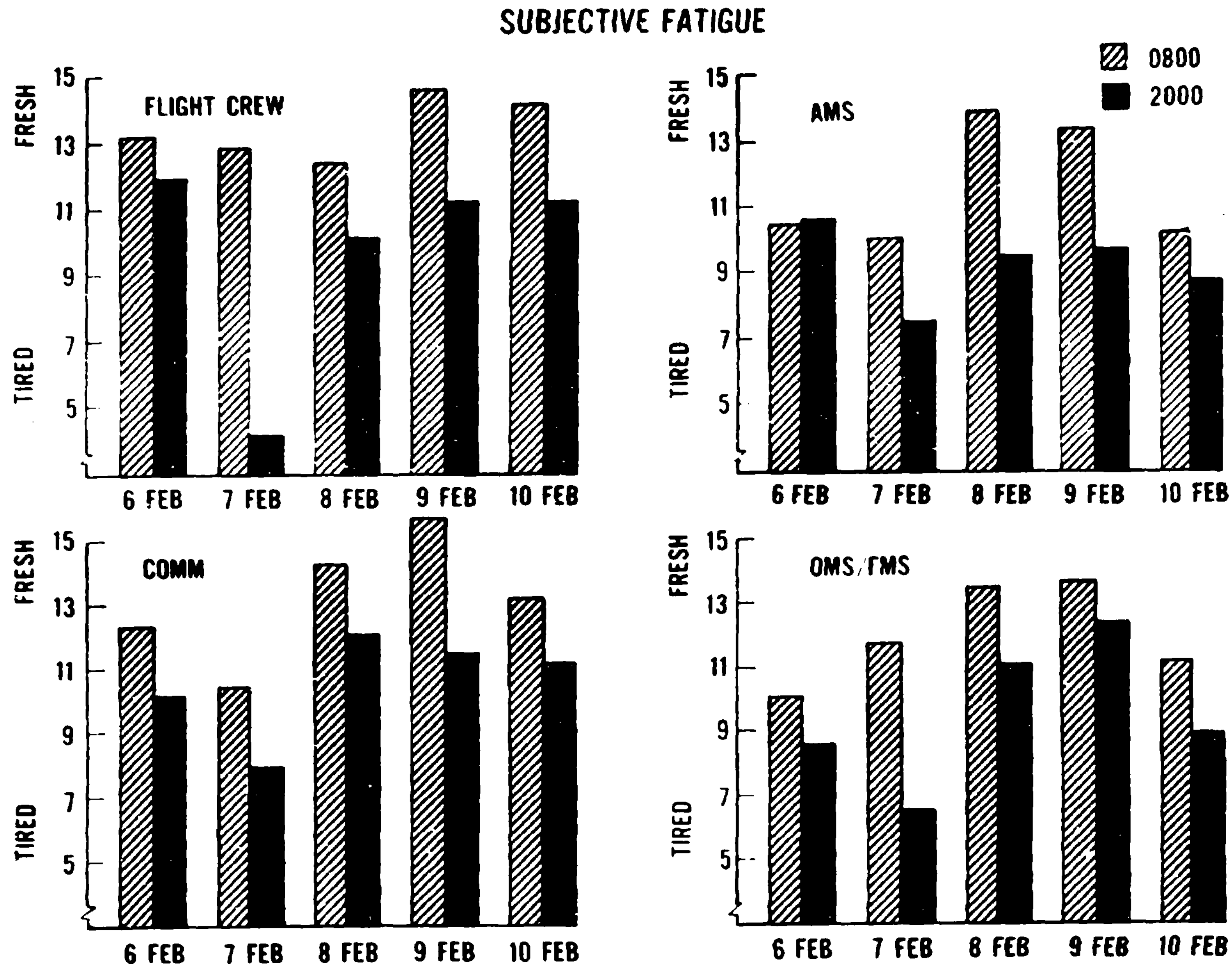


Figure 5. Mean subjective fatigue scores reported (SAM Form 136) by four crew groups at 0800 and 2000 during and after the mission.

Both mission and postmission mean subjective fatigue scores are presented in Figure 5 for 0800 and 2000 on each day of the study. Although some of the mean scores presented in Figure 5 are also presented in Figure 4, the format of Figure 5 highlights some group differences in patterns of change during the mission. Comparing the fatigue levels for each group at 0800/6 February and 0800/7 February, essentially no difference occurred for the flightcrew and AMS personnel; the COMM group reported a moderate increase in fatigue, while the OMS/FMS group felt less fatigued. The OMS/FMS group acquired a large average amount of sleep (>10 hours) during the mission. Most of that sleep (96%) occurred during the first 24 hours of the mission. The recuperative value of this sleep, even though acquired in the airborne-mission environment, was reflected in the reduced fatigue (higher scores) reported by the OMS/FMS personnel at 24 hours into the mission.

For each crew category, the greatest amount of subjective fatigue (lowest scores) reported at any time during the study occurred at 2000 on the evening of 7 February after landing at Offutt AFB (Figs. 3 and 5). The mean score of only 4.2 for the flightcrew at 2000, while based on only 5 of the 9 members (the others had already retired for the night), was particularly indicative of intense feelings of fatigue. The effects of the previous 40-48 hours, combined with the opportunity to "let down" upon entering home-base postmission crew rest, contributed to the high levels of subjective fatigue reported by most participants on this first evening after mission completion.

Statistical comparison of fatigue scores reported at 1600 and 2000 on each day of the evaluation indicated significant differences among days ($p<.001$) and between times ($p=.023$). In addition to those of the NEACP group, the stewards' scores were omitted from this analysis because of considerable missing data. The day effect resulted primarily from the low mean value reported after landing on 7 February, although the midflight value reported on 6 February was also significantly lower than the average recovery value (Table 4). The between-times difference in the overall mean score of 11.4 at 1600 versus 10.0 at 2000 reflects the consistency of the circadian pattern in subjective feelings of fatigue.

TABLE 4. OVERALL MEAN SUBJECTIVE FATIGUE SCORES FOR 1600 AND 2000 DURING AND AFTER 30-HR AIRBORNE MISSION

Day	Mean fatigue score
6 Feb*	9.9
7 Feb	7.9
8 Feb	11.6
9 Feb	12.5
10 Feb	10.9

*airborne

After a night of extended good quality sleep at home (10.1 hours), the crews were considerably recovered and refreshed on the first postmission day,

as indicated in Figures 3 and 5 by the elevated scores on 8 February. Comparing scores reported at 0800 and 1200 (NEACP omitted) during the last portion of the mission (7 Feb) with those reported at the same times after the first night of recovery (8 Feb), a significant increase (p=.002) in daily mean fatigue score occurred: the average score was 10.9 during the final airborne hours and 13.4 a day later.

The mean subjective fatigue scores reported during the first and second complete postmission days (8 and 9 Feb), plus the need for only normal amounts of sleep on the second postmission night, indicated complete recovery on the morning of 9 February, about 40 hours--and more importantly, two nights of restful sleep--after mission completion. The relatively lower subjective fatigue scores reported on 10 February, the last day of postmission evaluation, are probably not related to mission effects. While no definite explanation can be offered, 10 February was a Saturday, and the conclusion of the 45-day test period was celebrated the Friday night before by several of the test participants. The postmission fatigue scores collected at 0800, 1200, 1600, and 2000 on 8, 9, and 10 February were submitted to analysis of variance for all participating crew groups but the stewards, for whom too much data was missing. Significant crew-group (p=.019), day (p=.026), and time-of-day (p=.004) effects occurred (Table 5). The time-of-day effect resulted from typical circadian variation. Additional testing of the day means indicated no change from 8 to 9 February, but a significant decrease in score from 9 to 10 February.

TABLE 5. MEAN SUBJECTIVE FATIGUE SCORES FOR CREW GROUPS, TIMES OF DAY, AND DAYS OF POSTMISSION RECOVERY

	Mean fatigue score
Crew group	
Flightcrew	14.0
COMM	14.0
OMS/FMS	10.7
AMS	11.4
Time-of-day	
0800	13.2
1200	13.4
1600	12.5
2000	10.6
Postmission day	
8 Feb	12.5
9 Feb	13.5
10 Feb	11.6

Mood States

As with the SAM subjective fatigue data, circadian effects must also be considered when evaluating the six subjective mood states derived from the

POMS. In this study, legitimate comparisons could be made on the two sets of POMS data collected while airborne; by design, these data were collected at 0800 on both 6 and 7 February. Similarly, the two sets of postmission POMS data allow comparison since these data were collected at 1600 on both 7 and 9 February. The POMS scores for the OMS/FMS personnel were more variable for most of the affective dimensions than were the scores for the other crew groups. Therefore, the OMS/FMS data were omitted from statistical analysis. However, the mean POMS fatigue scores presented in Figure 3 do include OMS/FMS scores so as to permit ready comparison with the SAM Form 136 subjective fatigue scores.

Overall day/time means are presented in Table 6 for each affective dimension. From shortly after takeoff (6 Feb/0800) to 24 hours into the mission (7 Feb/0800), POMS vigor decreased and fatigue and confusion increased ($p<.01$ in all cases). When POMS scores collected shortly after landing (7 Feb/1600) were compared with those collected 48 hours later (9 Feb/1600), anger, fatigue, and confusion had decreased and vigor had increased ($p<.01$ in all cases). The magnitudes of these POMS changes were considerably greater for fatigue and vigor.

TABLE 6. MEAN POMS T-SCORES DURING AND AFTER 30-HR AIRBORNE MISSION

Affective dimension	Airborne		Postmission	
	6 Feb/0800	7 Feb/0800	7 Feb/1600	9 Feb/1600
Anxiety	37.8	38.7	38.5	34.9
Depression	38.5	38.2	38.5	37.5
Anger	40.0	39.8	41.1	38.4
Vigor	52.3	45.8	43.3	53.0
Fatigue	41.0	46.5	50.6	39.0
Confusion	34.6	36.5	37.3	33.3

A significant crew-group x day interaction ($p=.037$) appeared when the postmission anxiety scores were compared. As summarized in Table 7, mean anxiety scores for the flightcrew and COMM personnel collected just after landing (7 Feb/ 1600) were greater than those for the stewards and AMS personnel. Two days later (9 Feb/1600), the mean anxiety scores for the stewards and AMS personnel were essentially unchanged and the mean anxiety scores for the flightcrew and COMM personnel had decreased to comparable values.

TABLE 7. POSTMISSION POMS MEAN ANXIETY SCORES

Crew group	7 Feb/1600	9 Feb/1600
Flightcrew	40.8	36.0
Stewards	36.0	35.3
COMM	39.1	33.5
AMS	36.6	35.9

Pearson product moment correlation coefficients (r) between the SAM Form 136 subjective fatigue scores and the POMS fatigue scores are shown in Table 8 for each of the four times the POMS was administered.

TABLE 8. MEAN r-VALUES BETWEEN FATIGUE SCORES FROM SAM FORM 136 AND POMS

Day/Time	r	n	p
6 Feb/0800	-.75	64	<.001
7 Feb/0800	-.68	64	<.001
7 Feb/1600	-.81	29	<.001
9 Feb/1600	-.45	29	<.05

Biochemical Measures

The urinary measures were statistically analyzed in log units and converted back to standard units for tabular presentation. Overall mean values for each crew group are presented in Table 9; day-to-day postmission mean values are presented in Table 10. Significant between-group differences occurred for 17-OHCS, epinephrine, and amino nitrogen ($p<.05$ in all cases). Significant differences among the day means occurred for 17-OHCS ($p<.01$), urea, sodium, and Na/K ($p<.05$ in each case). Additional analysis of the day means revealed that the 17-OHCS effect had resulted from a relatively low level on the first complete postmission day (8 Feb). A notable decrease from immediately postmission (7 Feb) to 1 day later (8 Feb) was responsible for the significant urea finding. The significant differences in the daily sodium and Na/K urinary levels were the result of the elevated sodium levels in the samples collected soon after landing.

DISCUSSION

During the 30-hour E-4B mission, the subjective fatigue levels reported were moderate and not of a magnitude associated with compromises in performance and safety. Although not of the best quality, the sleep acquired inflight in the bunks, in the passenger seats, and even on the floor was of restorative value and contributed to the general absence of severe fatigue and negative mood states during the mission. The high quality of the meals and the comfortable bioenvironment also contributed to the maintenance of crew motivation and morale.

After mission completion, psychobiological stress was present for about 1 1/2 days. Severe levels of subjective fatigue were reported on the afternoon and evening following mission completion and entry into postmission crew rest. At the same time, urinary levels of urea and sodium and the Na/K ratio were greater than they were on the 3 subsequent postmission days, indicating increased metabolic activity during the latter hours of the 30-hour mission. After the first postmission night, in which an average of 10 hours of sleep was acquired (2-3 hours more than usual), the crewmen were considerably recovered and felt generally refreshed throughout the first complete postmission day.

TABLE 9. OVERALL MEAN URINARY CONCENTRATIONS FOR CREW GROUPS

Biochemical measure	Crew group				
	Flightcrew	Stewards	COMM	AMS	OMS/FMS
17-OHCS[a] (μg)	382	383	495	393	324
Amino Nitrogen[a] (mg)	8.70	7.69	8.78	6.58	5.80
Epinephrine[a] (μg)	1.103	0.774	0.718	0.587	0.650
Norepinephrine (μg)	2.08	1.80	1.40	1.02	1.09
Urea (mg)	1209	1302	1372	1090	1190
Sodium (mEq)	11.04	8.66	11.02	10.39	9.88
Potassium (mEq)	3.89	3.47	4.49	3.86	3.74
Na/K	2.83	2.50	2.41	2.69	2.55

[a]Between-group effect: $p<.05$

TABLE 10. MEAN URINARY CONCENTRATIONS FOR EACH POSTMISSION DAY

Biochemical measure	Postmission day			
	7 Feb	8 Feb	9 Feb	10 Feb
17-OHCS[a] (μg)	451	333	427	412
Amino nitrogen (mg)	8.10	6.88	7.18	7.96
Epinephrine (μg)	0.818	0.699	0.779	0.776
Norepinephrine (μg)	1.38	1.40	1.52	1.42
Urea[b] (mg)	1293	1078	1207	1191
Sodium[b] (mEq)	12.52	9.17	9.84	10.19
Potassium (mEq)	4.21	3.80	4.37	4.19
Na/K[b]	3.07	2.41	2.25	2.43

[a]Between-day effect; $p<.01$
[b]Between-day effect, $p<.05$

Urinary levels of urea and sodium decreased to levels that remained stable for the balance of the postmission evaluation. However, as indicated by a relatively low urinary level of 17-OHCS, adrenocortical activity was depressed 1 day after mission completion, suggesting physiological recovery was not yet complete. After the second postmission night of an uninterrupted, typical amount of sleep, the crewmen had recovered sufficiently to resume normal ground and flight duties. The subjective fatigue scores were of normal amplitude and pattern, and the urinary concentrations of each of the biochemical measures had stabilized.

The sequential changes in the subjective fatigue scores and the biochemical measures, particularly urinary sodium, are similar to those previously observed during and after extended-duration transport (4-7,9-11,14) and tactical (1,10,12,19) airborne missions and ground-based alert operations (10,18). A postmission night of good-quality uninterrupted sleep has consistently been the most important single counteraction against cumulative subjective fatigue (8,13,15,20). Almost a decade ago, Hale and associates (5) advocated urinary sodium as a very sensitive stress indicator and suggested that sodium, potassium, and Na/K determinations were very simple and rapid means of evaluating physiologic stress in large-scale field studies. In evaluating the POMS findings, it is important to note that, even with the conditions of the 30-hour mission, the mean scores for feelings of anxiety, depression, anger, and confusion were always less than the mean normative T-score of 50 established for normal, healthy young adults. Thus, while the direction and magnitude of changes in the mood scales provided information on crew status, at no time did the mean responses indicate even mildly disturbed affective states. Since crewmen selected for critical command and control missions have above-average physical and mental health, this finding is not surprising. The POMS and the SAM subjective fatigue scores corresponded very well. Both measures described increased feelings of fatigue at 24 hours into the mission, reflecting the effects of the extended duty hours interspersed with short periods of rest and sleep in the aircraft. After landing, participants indicated (by both measures) even greater feelings of fatigue; the SAM scores fell to a level usually described as severe. After 2 days and 2 nights of postmission crew rest, the two measures of fatigue agreed in describing recovery.

Generalizations are limited for crew fatigue findings for this single 30-hour mission flown in support of the IOT&E. This scheduling involved only one normal sleep period during the airborne mission. Greater crew fatigue could result from a 30-hour mission starting in the early evening hours because two normal sleep periods would be disrupted, the second during the final hours of the mission. Should the occasion arise for repeated missions lasting about 30 hours, it is recommended that 3 consecutive nights of sleep occur between the extended missions. Furthermore, the severe subjective fatigue reported after the 30-hour mission, about 36 hours after takeoff, are cause for some concern when considering the NEACP requirement of 72-hour continuously airborne capability. Although this finding was partially a consequence of entering postmission crew rest, the data suggest that severe levels of fatigue could occur during the last half of a 72-hour continuously airborne mission. The current fatigue findings for the 30-hour mission cannot be extrapolated to a 72-hour mission, as any accumulation of fatigue would be nonlinear. A continuously airborne mission of 72 hours for a system as large and complex as the E-4B is a unique exercise requiring empirical evaluation of operational capability.

CONCLUSION

The crew fatigue and stress levels that occurred during the 30-hour E-4B mission were moderate and did not indicate compromises in performance and safety. A few hours after mission completion, severe levels of fatigue were reported. After 2 nights of good-quality sleep in the home environment, the crewmen were sufficiently recovered to resume normal ground and flight duties.

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